Cartels and collusion in oligopoly

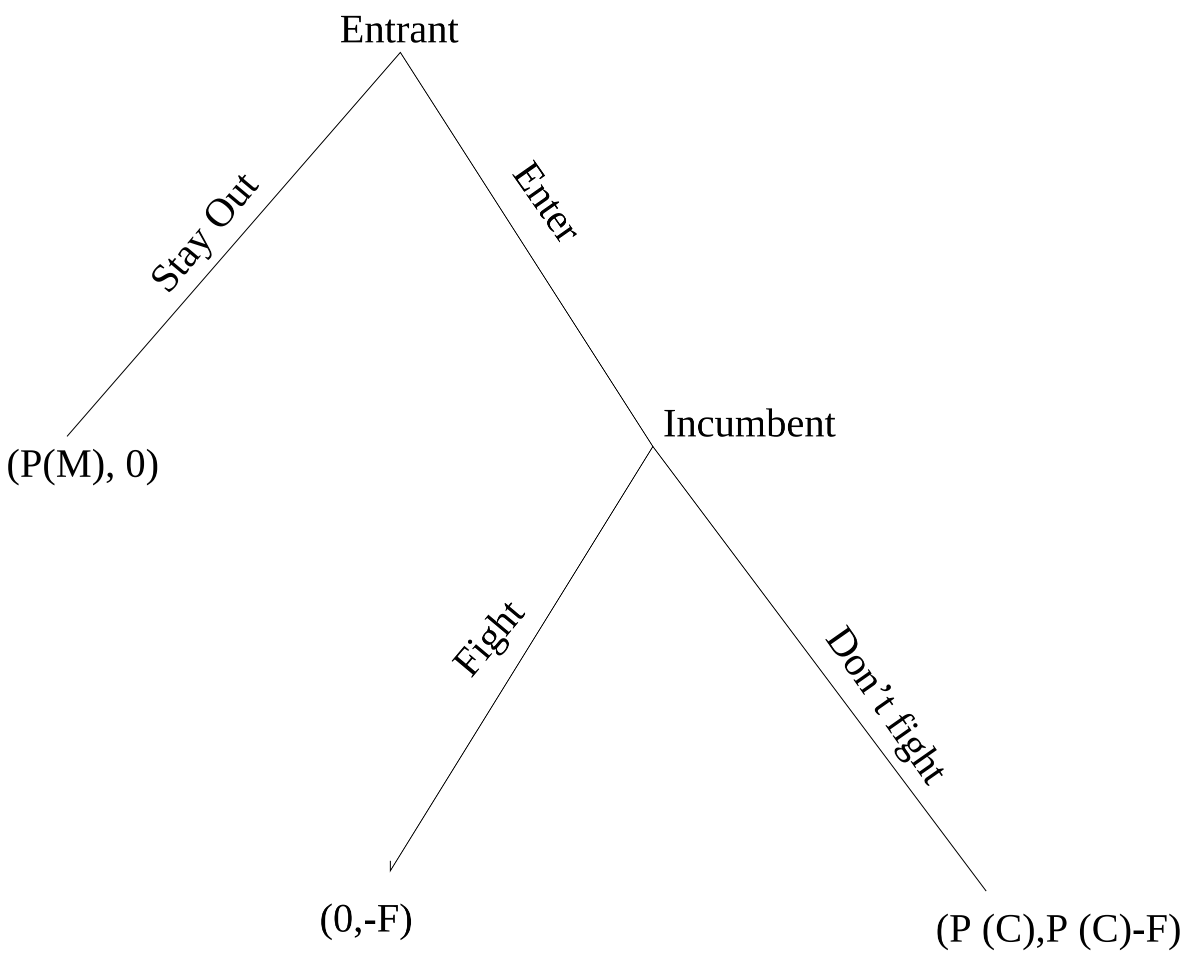
- Single-period non-cooperative Cournot game: unique NE when firms produce higher-output, receive lower profits than if they cooperated (prisoners' dilemma)
- Can cooperation occur in multi-period games?
- Equilibrium concept for multi-period games: **Subgame Perfect Equilibrium**
- Finitely-repeated Cournot game
- Infinitely-repeated Cournot game

Subgame-Perfect Equilibrium 1

- **Game:** model of interaction between a group of players (prisoners, firms, people)
- Each player (or firm) attempts to maximize its own payoffs
- Multi-period game most conveniently represented by a **game tree**. **Nodes** are junctures of game tree, at which a player moves.
- A **Strategy** for each player specifies an action to be taken *at each of her nodes.*
- A *subgame* is the part of the multi-period game that starts from any given node onwards.

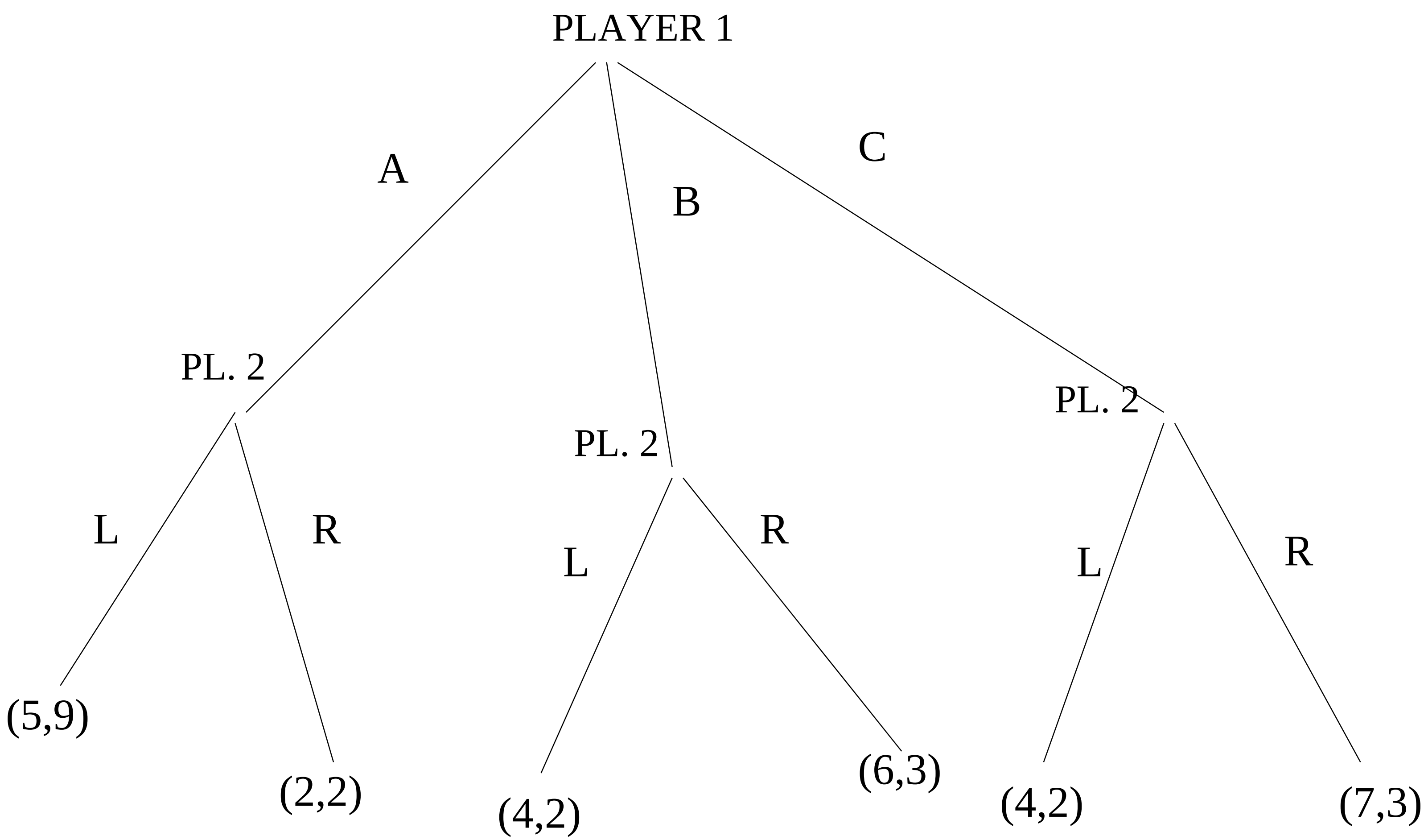
- Example 1: Limit pricing
  - Subgames?
  - Strategies for each player?
  - What are NE?
  - But what if entrant enters?
  - SPE: removes all non-credible threats, including incumbent's threat to counter entry with "limit pricing"

Example 1: Limit pricing



Subgame Perfect Equilibrium 2

- A **subgame perfect equilibrium** is a set of strategies, one for each player, from which, no player can receive a higher payoff *in any subgame*, i.e., each player's SPE strategy must be a best-response in any subgame
- All SPE are NE, not all NE are SPE
- Solve by backwards induction: consider following example


PLAYER 1
A
B
C
PL. 2
PL. 2
PL. 2
L
R
L
R
L
R
(5,9)
(2,2)
(4,2)
(6,3)
(4,2)
(7,3)

Subgame Perfect Equilibrium 3

Example 2: Are these equilibria, in any sense?

- $(A; (L, L, L))$: P2 “threatens” P1
- $(B; (L, R, R))$
- $(C; (L, R, R))$
- Backwards induction: eliminate all non-BR actions from player 2’s subgame

Finitely-repeated Cournot Game 1

2-firm Cournot quantity-setting game. Relevant quantities are:

- NE profits $\pi^* = \frac{(a-c)^2}{9b}$
- Cartel profits $\pi^j = \frac{(a-c)^2}{8b}$
- Firm 1 cheats on firm 2: $\pi^x = \pi_1(BR_1(q_2^j)) = \frac{9(a-c)^2}{64b}$
- Prisoners' dilemma analogy:

Firm 2 → Firm 1 ↓	cheat	cartel
cheat	$\frac{(a-c)^2}{9b}, \frac{(a-c)^2}{9b}$	$\frac{9(a-c)^2}{64b}, \frac{3(a-c)^2}{32b}$
cartel	$\frac{3(a-c)^2}{32b}, \frac{9(a-c)^2}{64b}$	$\frac{(a-c)^2}{8b}, \frac{(a-c)^2}{8b}$

Finitely-repeated Cournot Game 2

2-period Cournot game

- Firm 1 chooses quantities (q_{11}, q_{12})
  Firm 2 chooses quantities (q_{21}, q_{22})
- What are the subgames?
- What are SPE: solve backwards
- Second period: unique NE is (cheat,cheat)
- First period: (cheat,cheat) $\longrightarrow$ unique SPE is ((cheat,cheat), (cheat,cheat))
- What about ((cartel,cartel), (cartel,cartel))?
- What about ((cartel, cheat), (cartel, cheat))?
- What about
  Firm 1 plays (cartel; cheat if cheat, cartel if cartel)
  Firm 2 plays (cartel; cheat if cheat, cartel if cartel) ???
- What about 3 periods? N periods?

Infinitely-repeated Cournot Game 1

What if the 2-firm Cournot game is repeated forever? Are there SPE of this game in which both firms play q^{J*} each period?

- Discount rate $\delta \in [0, 1]$, which measures how "patient" a firm is.
- The "discounted present value" of receiving \$10 both today and tomorrow is $10 + \delta 10$.
- If $\delta = 1$, then there is no difference between receiving \$10 today and \$10 tomorrow.
- Property: $x + \delta x + \delta^2 x + \cdots + \delta^n x + \cdots = \frac{x}{1-\delta}$.

Infinitely-repeated Cournot Game 2

Proposition: If the discount rate is "high enough", then these strategies constitute a SPE of the infinitely-repeated Cournot game:

1. In period t, firm 1 plays $q_{1t} = q^j$ if $q_{2,t-1} = q^j$.
2. Play q^* if $q_{2,t-1} \neq q^j$.

Firm 1 cooperates as long as it observes firm 2 to be cooperating. Once firm 2 cheats firm 1 produces the Cournot-Nash quantity every period hereafter: **Nash reversion** (or "grim strategy").

Show that these strategies constitute a SPE by finding conditions such that they prescribe best-response behavior for firm 1 given that firm 2 is following this strategy also in each subgame.

Infinitely-repeated Cournot Game 3

Consider firm 1 (symmetric for firm 2).
There are two relevant subgames for firm 1.

1. After a period in which cheating (either by himself or the other firm) has occurred. Proposed strategy prescribes playing q^* forever, given that firm 2 also does this. This is NE of the subgame: playing q^* is a best-response to firm 2 playing q^*. This satisfies SPE conditions.

2. After a period when no cheating has occurred.
   - Proposed strategy prescribes cooperating and playing q^j, with discounted PV of payoffs $= \pi^j/(1-\delta)$.
   - The best other possible strategy is to play $BR_1(q_2^j) \equiv q_1^x$ this period, but then be faced with $q_2 = q^*$ forever. This yields discounted PV $= \pi^x + \delta(\pi^*/(1-\delta))$.
   - In order for q_j to be NE of this subgame, require $\pi^j/(1-\delta) > \pi^x + \delta(\pi^*/(1-\delta))$ (profits from cooperating exceed profits from deviating). This is satisfied if $\delta >$ **9/17**.
3. Therefore, the Nash reversion specifies a best response in both of these subgames if $\delta > 9/17$ ("high enough"). In this case, Nash reversion constitutes a SPE.

Note: Firms will never cheat under Nash reversion.

Infinitely-repeated Cournot game 4

Nash reversion is but one example of strategies which yield cooperative outcome in an infinitely-repeated Cournot game.

In general, firm 1 need not punish firm 2 forever to induce it to cooperate; after firm 2 deviates, just produce q^* for long enough so that it never pays for firm 2 to ever deviate. These “carrot and stick” strategies used to interpret price wars.

In general, the *Folk Theorem* says that, if the discount rate is “high enough”, an infinite number of SPE exist for infinite-horizon repeated games, which involve higher payoffs than in the single-period Nash outcome.

δ “high enough”: punishments must be severe. If δ too low, firm 2 prefers higher profits from cheating now, undeterred from lower future profits from firm 1’s punishment.

Infinitely-repeated Cournot Game 5

Generally: threats of punishment must be *credible* — it must be a firm's best-response to punish when it detects cheating

Industry and/or firm characteristics can make punishments more credible:

1. Flexible capacity: punishment may involve a large hike in quantity, this must be relatively costless
2. Good monitoring technology: cheating must be detected rather quickly. Trade journals facilitate collusion? Fewer number of firms?
3. Demand uncertainty foils detection of cheating: is low profits due to lower demand or cheating?
4. Homogeneous products: so firm 1 can hurt firm 2 by producing more

Main lessons

- Notion of Subgame perfect equilibrium
- No cooperation in finitely-repeated Cournot game
- Cooperation possible in infinitely-repeated Cournot game